TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 480

THE DRAG OF STREAMLINE WIRES

By Eastman N. Jacobs
Langley Memorial Aeronautical Laboratory

Washington
December 1933

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE NO. 480

THE DRAG OF STREAMLINE WIRES

By Eastman N. Jacobs

SUMMARY

Preliminary results are given of drag tests of stream-
line wires. Full-size wires were tested over a wide range
of speeds in the N.A.C.A. high-speed tunnel. The results
are thus directly applicable to full-scale problems and
include any compressibility effects encountered at the
higher speeds.

. The results show how protuberances may be employed on
conventional streamline wires to reduce the drag, and also
show how the conventional wires compare with others having
sections more like strut or symmetrical airfoil sections.

Because the new wire sections developed are markedly
superior aerodynamically to conventional wires, it is rec-
ommended that some of them be tested in service in order
to investigate their relative susceptibility to vibration
and to fatigue failure.

INTRODUCTION

Although the drag of the lenticular section commonly
employed for streamline wires has been known for many
years to be rather large as compared with that of the best
strut sections, flow observations made recently in the
N.A.C.A. smoke tunnel again called particular attention to
the fact that the flow about the lenticular section should
be considered unsatisfactory. Separation of the flow from
the surface may occur nearly as far forward as mid section,
leaving a wide dead-air region and a turbulent wake. Pro-
tuberances were placed on the lenticular section with the
expectation that the turbulence created by them would, by
scouring out the dead air, improve the entire flow. Ob-
servations of the flow about an enlarged replica of a
streamline wire (c = 10 inches) in the smoke tunnel (see
fig. 1) indicated that the flow was definitely improved
by the addition of protuberances, but the drag could not

be inferred from the flow observations with sufficient accuracy to permit the determination of the optimum protuberance size, position, and shape.

Following these investigations the Bureau of Aeronautics, Navy Department, requested the N.A.C.A. to make comparative drag tests of standard streamline wires and of two new ones supplied by the Navy Department and here designated as B wires, one having a strut-type section of normal fineness ratio and the other a section of small fineness ratio. This request resulted in the combining of the investigations and the transferring of the tests to the high-speed wind tunnel, where full-scale wires could be tested at full speed and the drags accurately measured. A test program was formulated and extended to include the investigation of various wire section shapes. The research is not yet complete, this report being a preliminary one presenting the results obtained to date.

WIRE SECTIONS

Two streamline wires having lenticular sections were used in the investigation. The first, which will be referred to as the small standard wire, was a nominal 5/16-inch streamline wire that had been in service and was not refinished before testing. The measured section is shown on figure 2. The other one is referred to as the large standard wire, and was a specially made model having the S.A.E. specified shape (reference 1) but of the same size as a service nominal 1/2-inch streamline wire. As compared with the small standard wire it therefore had a relatively accurate form and a smooth surface. This wire is the one that was tested with protuberances, which consisted of small round wires soldered along its surfaces.

The two B wires have sections similar to strut sections, as shown by the profiles drawn in figure 2 plotted directly from measurements of the sections from an arbitrary axis. The one that will be referred to as the thick B section has a small fineness ratio, and the other, the thin B section, has approximately a normal fineness ratio for a streamline wire.

The new sections investigated were developed from the N.A.C.A. family of airfoils, the section numbers being as follows:

N.A.C.A. 0025-34

N.A.C.A. 0025-63

N.A.C.A. 0025-64

N.A.C.A. 0025-65

The 0025 denotes a symmetrical airfoil of thickness 0.25c (fineness ratio 4). The numeral 6 following the dash denotes the normal leading-edge radius, and the numeral 3 a smaller leading-edge radius. The last figure denotes the distance from the leading edge to the position of maximum thickness expressed in tenths of the chord. These profiles are included in figure 7. Some important geometrical characteristics of all the sections investigated and the ordinates of the N.A.C.A. 0025-63 profile are given in table I.

TESTS

The tests were made in the N.A.C.A. high-speed tunnel, a description of which may be found in reference 2. The wires were arranged to pass through the 11-inch-diameter closed air stream of the tunnel, and were mounted on the special balance in such a way that tension could be applied to them. Observations of the drag and dynamic pressure were taken at uniform increments of V/V_c, where V_c is the velocity of sound.

RESULTS

The results are presented in figures 3, 4, 5, 6, and 7, as curves of the drag coefficient against Reynolds Number, and the speed is shown by numbers on the plotted points indicating the value of the ratio of V/V_c. In order to facilitate the comparison of wires of equal strength, the area used in calculating the drag coefficient is ($l\sqrt{\text{cross-sectional area}}$), where l is the length of the wire exposed to the air stream. Similarly, for the

Reynolds Number, the square root of the cross-sectional
area is used as the characteristic dimension. Thus, equal
drag coefficients correspond to equal drags for wires hav-
ing approximately equal strengths, and similarly equal
Reynolds Numbers correspond to equal velocities for wires
of equal strengths. The drags and Reynolds Numbers are
therefore computed from the formulas

$$D = C_D \frac{\rho V^2}{2} l \sqrt{\text{cross-sectional area}}$$

$$R = \frac{V \sqrt{\text{cross-sectional area}}}{\nu}$$

where C_D and R are the drag coefficient and the Reynolds
Number, respectively, l is the length of the wire, ρ
the mass density of the air, and ν the kinematic viscos-
ity. The areas and lengths as well as the other quanti-
ties must, of course, be expressed in consistent units.
It should also be noted that if the data are employed to
determine the drag of wires at very high speeds and under
any given atmospheric conditions, the curves as plotted
cannot be taken to give correctly the drag coefficient
at a given Reynolds Number for a wire of the size tested,
but apply accurately only to wires for which the Reynolds
Number and V/V_c ratio of the tests are both reproduced.

DISCUSSION

Standard wires.- In reference to the curves in figure
3, representing the drags of the standard lenticular-
section wires, a comparison of the curves for the two
wires indicates that the drag may be to a considerable ex-
tent dependent on the accuracy of the section form and the
condition of its surface. The higher drag of the smaller
wire at the high Reynolds Numbers may, however, be due to
certain compressibility effects that may occur at lower
speeds for the smaller wire. The drag of the larger wire
drops from a coefficient of approximately 0.2 at a Reynolds
Number of 20,000 to approximately 0.09 at a Reynolds Num-
ber of 70,000. This range of the Reynolds Number corre-
sponds to speeds between 79 and 275 miles per hour for a
nominal 1/2-inch streamline wire for standard atmospheric
conditions at sea level.

A comparison of these results with the results of some drag measurements of streamline wires made several years ago in the N.A.C.A. variable-density tunnel (reference 3) may be of some incidental interest. The comparison shows fairly satisfactory agreement except that the present results, which are from tests in the comparatively nonturbulent air stream of the high-speed tunnel, show the drop of the drag coefficient to occur at values of the Reynolds Number about 70 percent higher.

B wires.- Referring again to figure 3, it is seen that the thick B wire, owing to its excessive drag, is of little interest. The thin B wire, however, gives a considerably lower drag than either standard wire, although other tests to be discussed later indicate that better wires may be developed. Tests were made to investigate the thin B wire at small angles of attack. The results, which are shown in figure 4, like other results obtained for a standard wire which was also tested at a few small angles of attack, indicate that the drag may be somewhat reduced at the lower values of the Reynolds Number. The dissymmetry of the curves at negative and positive angles is probably due to dissymmetry of the section. (See fig. 2.) The axes of the sections from which the angles were measured were determined with respect to 90° V blocks clamped on the wires at the leading and trailing edges.

Protuberances.- One of the drag curves shown in figure 3 indicates the characteristics of the large standard wire with the optimum protuberance arrangement found as a result of these tests. The protuberances consist of two 0.004c-diameter round wires soldered along the surface of the main wire at the mid-section position. These results show that the drag of the lenticular section may be made to approach that of a streamline section by the addition of protuberances. The results of varying the protuberance size (fig. 5), which are from tests with the protuberance located at the quarter-chord position, indicate that the smallest protuberance is the most satisfactory. The effects of this protuberance were then studied as the protuberance position was varied as shown in figure 6. These results indicate that the mid-position is the most satisfactory, which is very fortunate because it is by far the most practical position from the standpoint of the manufacturer or operator.

Special sections.- The characteristics of the new streamline wire sections developed from the N.A.C.A. fam-

ily of airfoils are compared with the characteristics of the standard lenticular section in figure 7. These results indicate that the position of maximum thickness for the section should be well forward, as shown by the fact that the 0025-63 section gives the best characteristics. It will be noted that this section is markedly superior to the standard lenticular section for all Reynolds Numbers and speeds within the useful range. In other words, even when the lenticular section is operating at its minimum drag coefficient a further reduction in drag of approximately 40 percent is possible by substituting the N.A.C.A. 0025-63 section. The advantages of this section over the lenticular section with protuberances are less marked, however, and other advantages of the lenticular section, including its fore and aft symmetry permitting tensioning adjustments to be made in half-turn stops, will probably dictate the immediate adoption of the section with protuberances in preference to an airfoil section.

RECOMMENDATION

It is recommended that wires having the lenticular section with protuberances and wires having the N.A.C.A. 0025-63 section be given service tests in order to determine whether or not they are more subject to vibration or to fatigue failure than standard streamline wires.

Langley Memorial Aeronautical Laboratory,
      National Advisory Committee for Aeronautics,
            Langley Field, Va., November 6, 1933.

REFERENCES

1. Society of Automotive Engineers: S.A.E. Handbook, Soc. Auto. Eng., Inc. (New York). 1933 edition, p. 206.

2. Stack, John: The N.A.C.A. High-Speed Wind Tunnel and Tests of Six Propeller Sections. T.R. No. 463, N.A.C.A., 1933.

3. DeFoe, George L.: Resistance of Streamline Wires. T.N. No. 279, N.A.C.A., 1928.

TABLE I

CROSS-SECTION AREAS AND FINENESS RATIOS

in terms of the chord c, and the thickness t

Model	Area	Fineness $\frac{c}{t}$
Thin B wire	0.742 c t	3.66
Thick B wire	.734 c t	2.00
5/16-inch standard wire	.760 c t	3.88
1/2-inch standard wire	.760 c t	4.00
N.A.C.A. 0025-34	.703 c t	4.00
N.A.C.A. 0025-63	.696 c t	4.00
N.A.C.A. 0025-64	.720 c t	4.00
N.A.C.A. 0025-65	.754 c t	4.00

Ordinates of the N.A.C.A. 0025-63 section

Station	Ordinate	Station	Ordinate
0.0125	0.0399	0.40	0.1218
.025	.0553	.50	.1127
.05	.0754	.60	.0983
.075	.0891	.70	.0794
.10	.0993	.80	.0566
.15	.1128	.90	.0308
.20	.1204	.95	.0169
.30	.1250	1.00	.0025
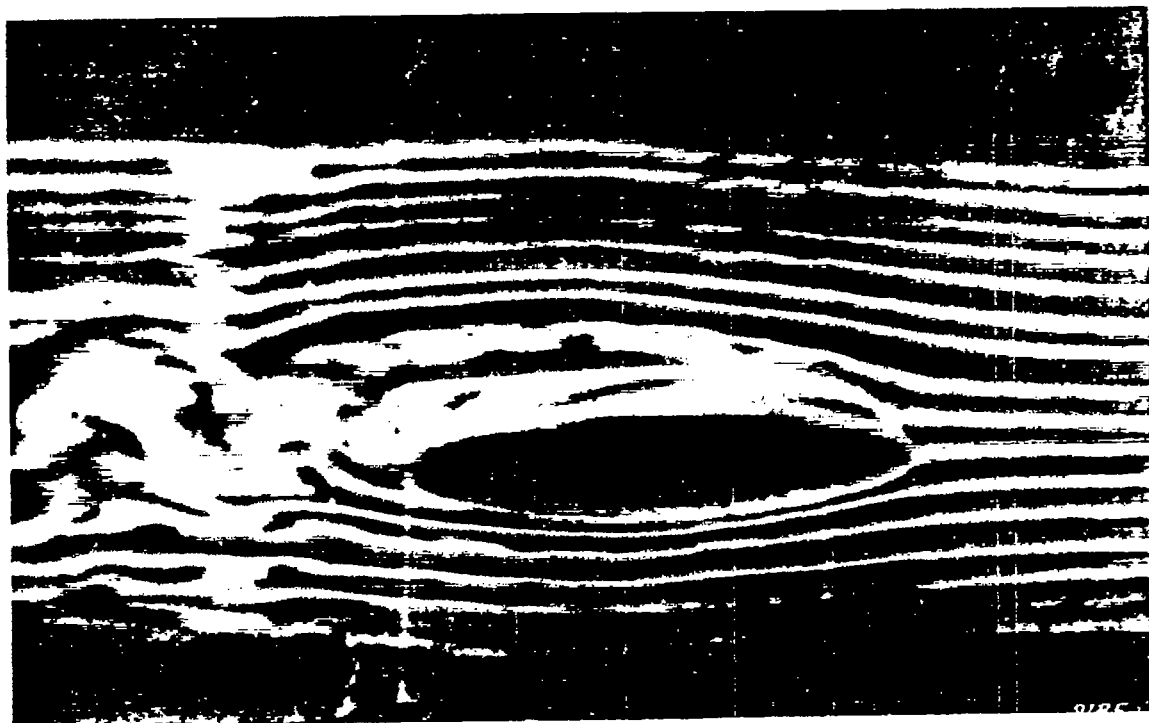
Without protuberances
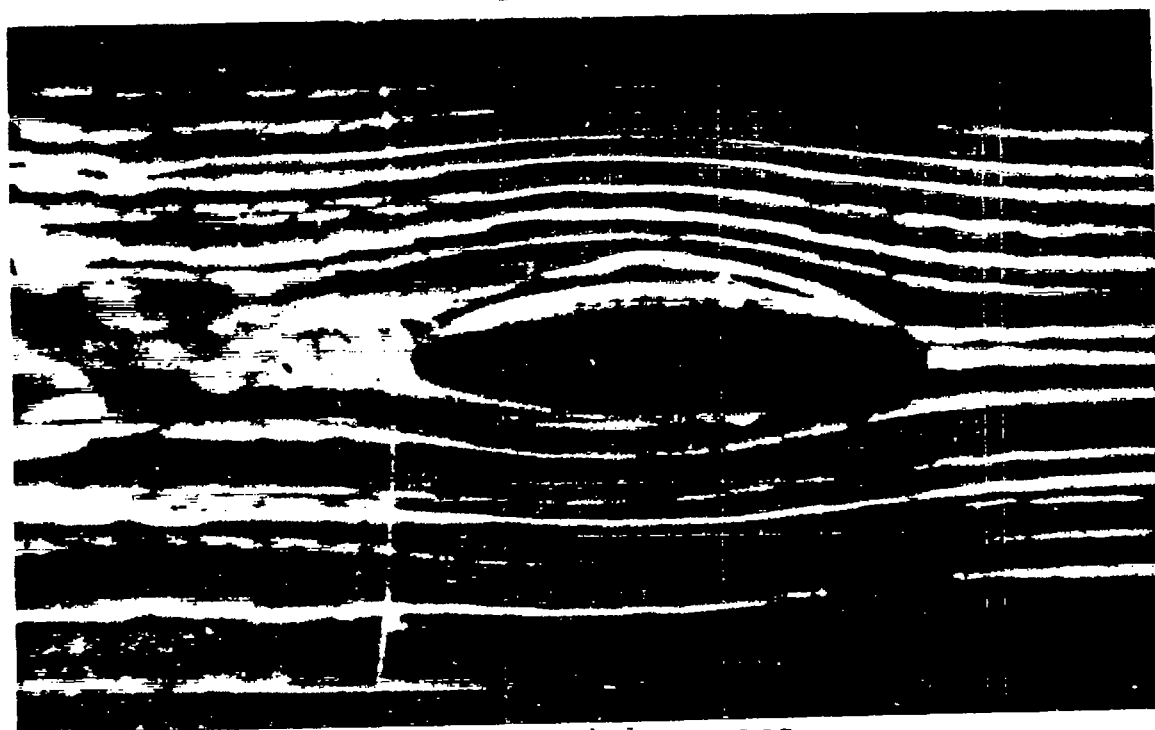
With protuberances

Figure 1.- Flow about a lenticular section as affected by pro-
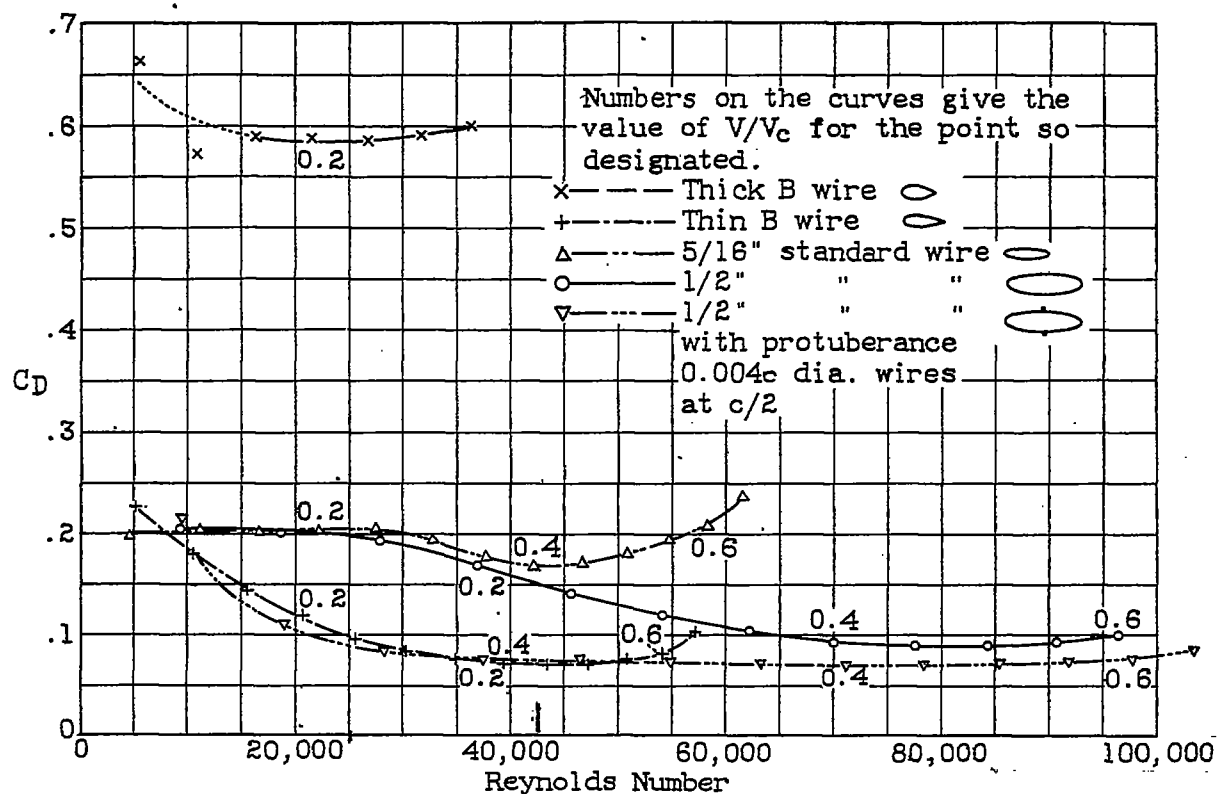   tuberances.

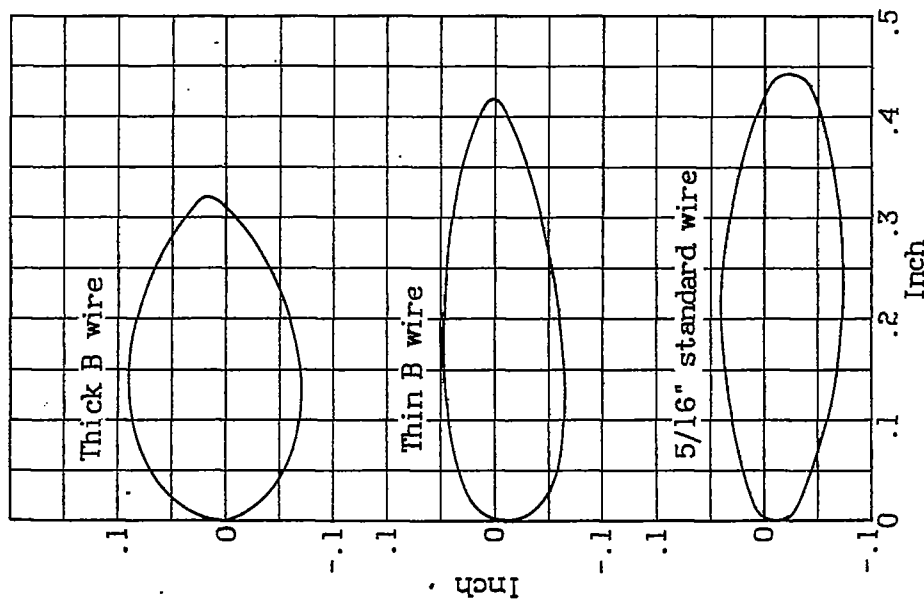Figure 3.- Drag coefficients for various streamline wires.

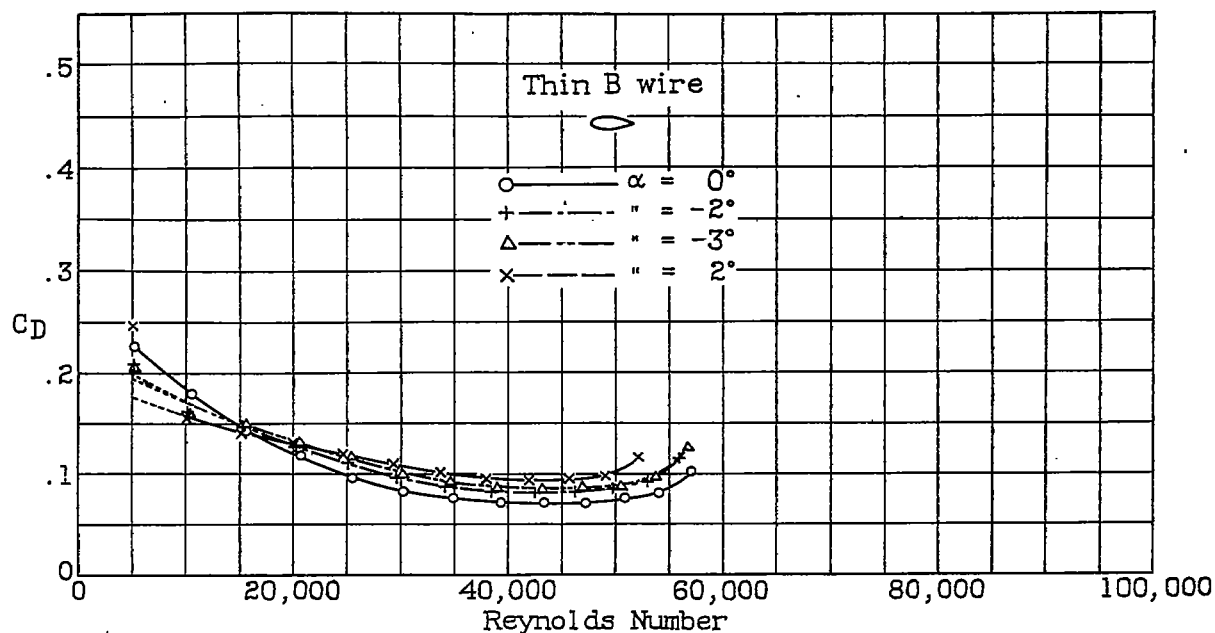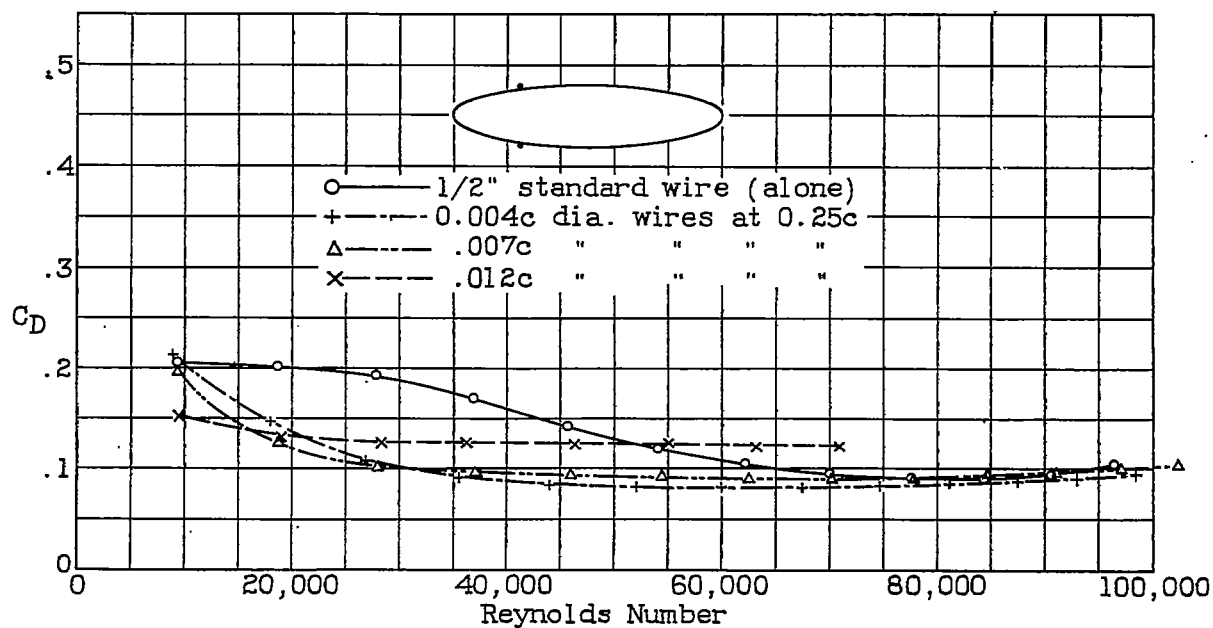Figure 2.- Measured profiles of streamline wires.

Figure 4.- C_D as affected by small variations of angle of attack

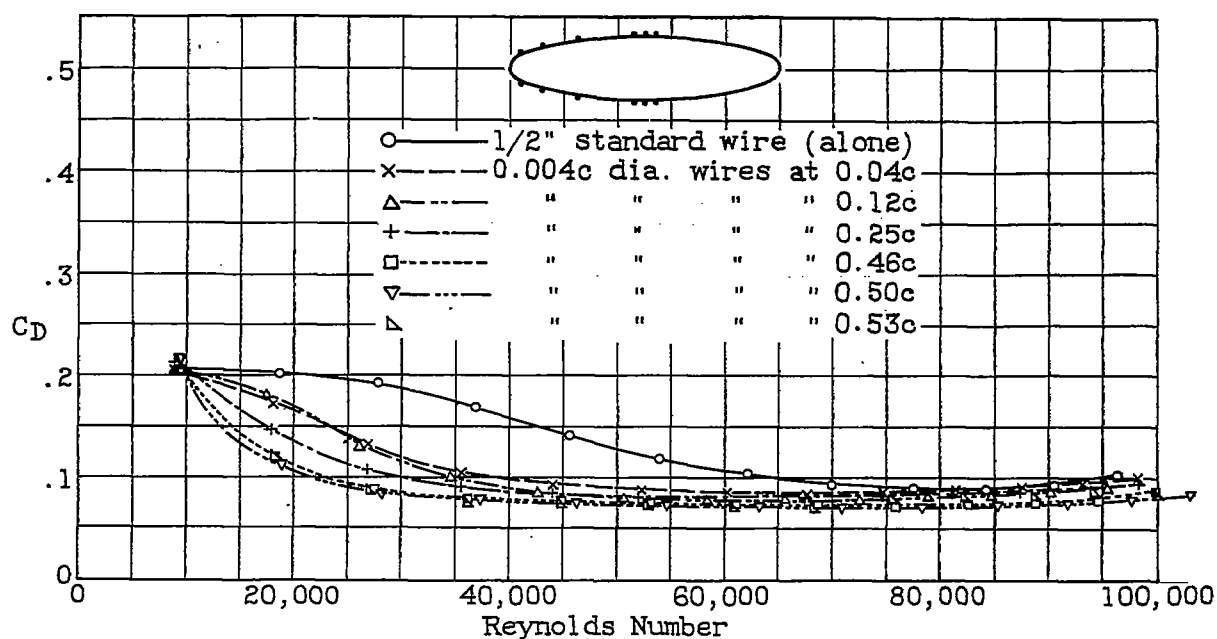Figure 5.- Variation of protuberance size.

Figure 6.- Variation of protuberance position.

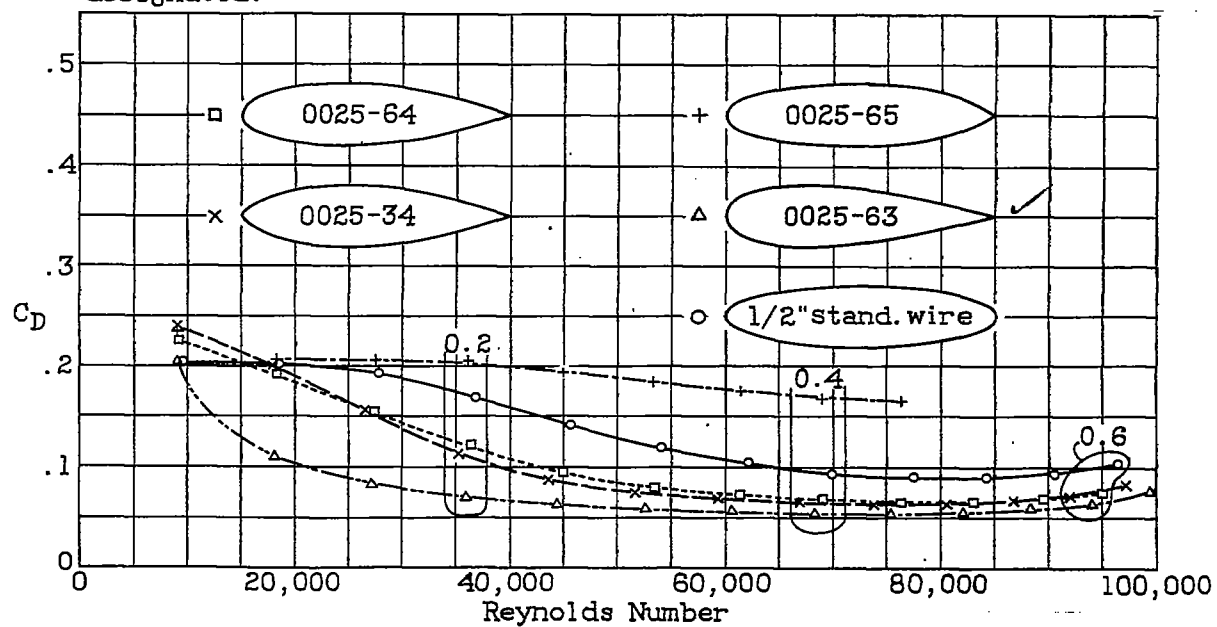Numbers on the curves give the value of V/V_c for the point so designated.

Figure 7.- Variation of section shape.